Performance Evaluation of Declarative Memory Systems in the Soar Cognitive Architecture

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Performance Issues in Supporting Persistent Real-time Behavior

1. Maintain reactivity as knowledge grows
   – *50-100 msec. real-time internal processing cycle*
2. Affordable memory requirements
   – *10's of Gbytes*

Our long-term goal is 1 year continuous operation

Today we will focus on 3 hours

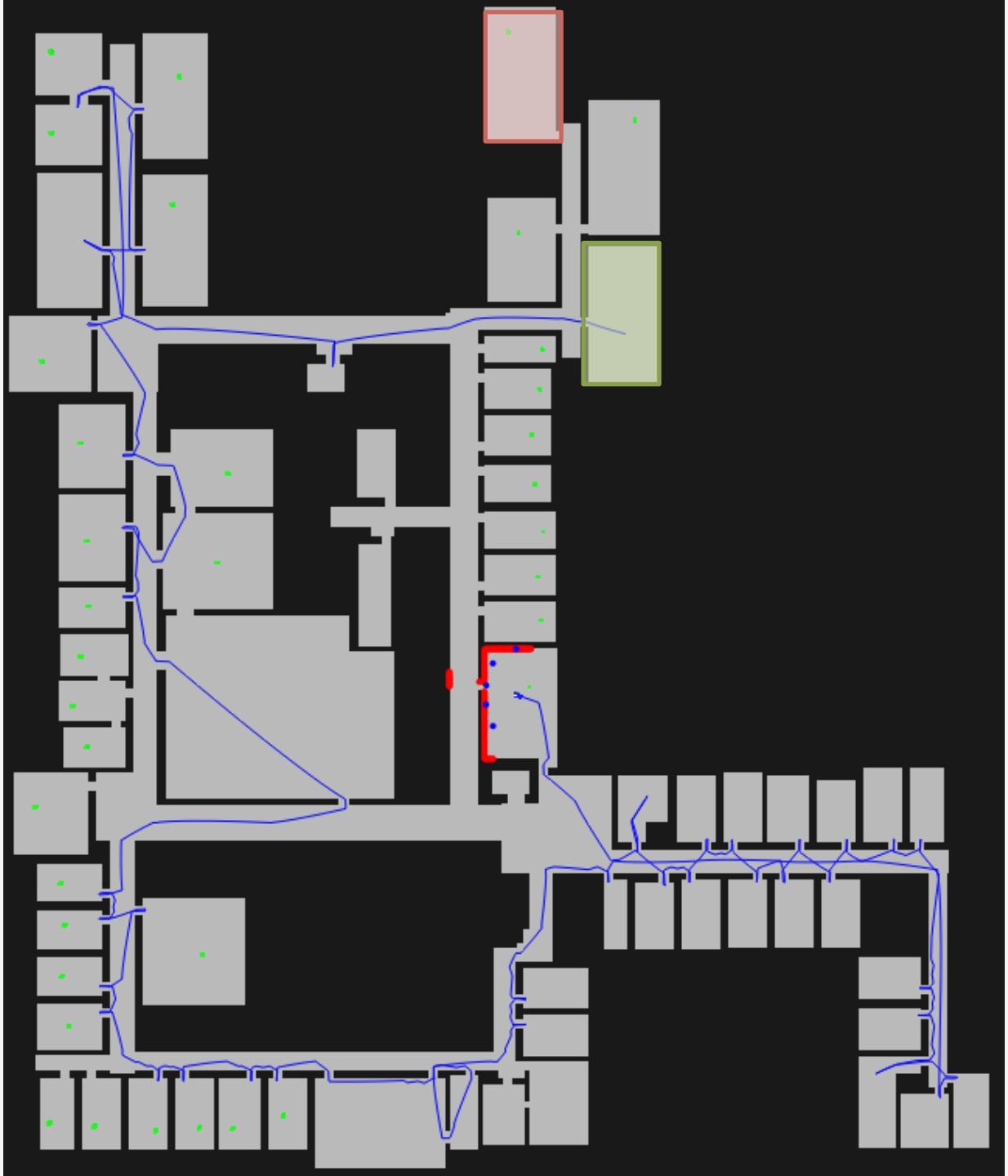
Outline of Talk

- Real-world Task: Mobile Robot Control
- Performance Evaluation of
  - Working Memory
  - Semantic Memory
  - Episodic Memory

- How do these memories perform on a real-world task where information grows over time?
- Does Soar meet our performance goals for a persistent learning agent?

Experimental Details

- Task: Find green square blocks in rooms and return them to the storage rooms.
  - Must plan routes
    - from blocks to storage area,
    - storage area to blocks, and
    - storage area to unvisited areas.
- Use map of 3rd Floor of Michigan CSE Building:
  - >100 rooms, 100 doorways, 70 objects
- All runs 3 hours real time: 10800 seconds
  - ~25-30M processing cycles
  - Aggregate data 10 sec. bins (70K cycles)



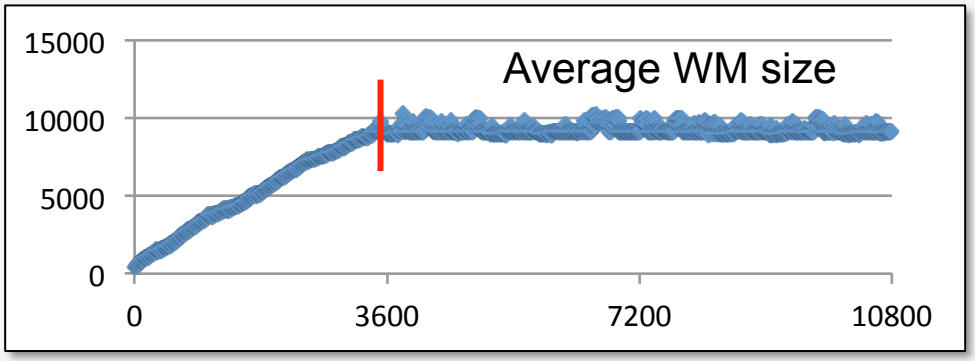
Working Memory

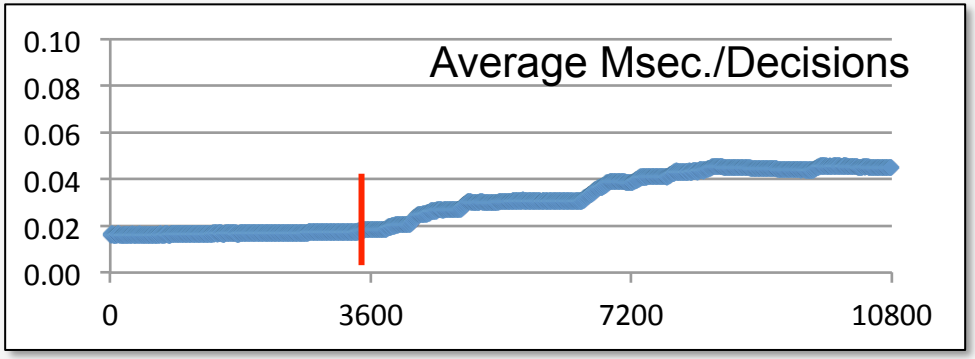
- Agent's current awareness
  - Interface to perception, action, and long-term memories
  - Relational graph structure
- In this task
  - Maintain complete map in working memory
    - Rooms, walls, gateways, objects
  - Impacts performance because of rule matching

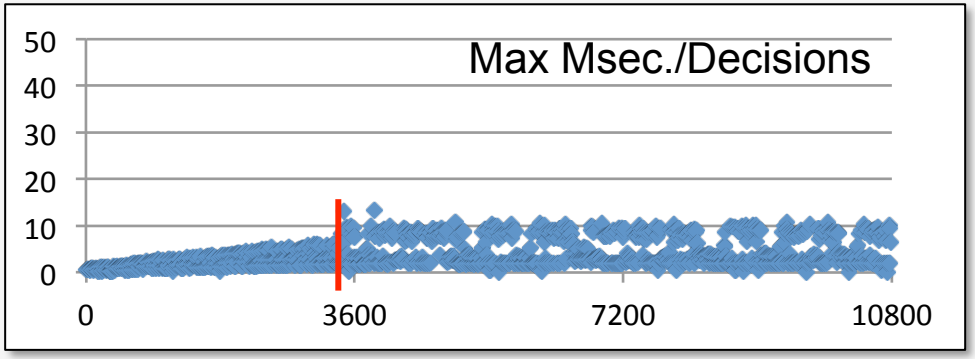
Working Memory Results

Map in Working Memory
Includes map of rooms, walls, and doors and location of each object

When robot finds storage room







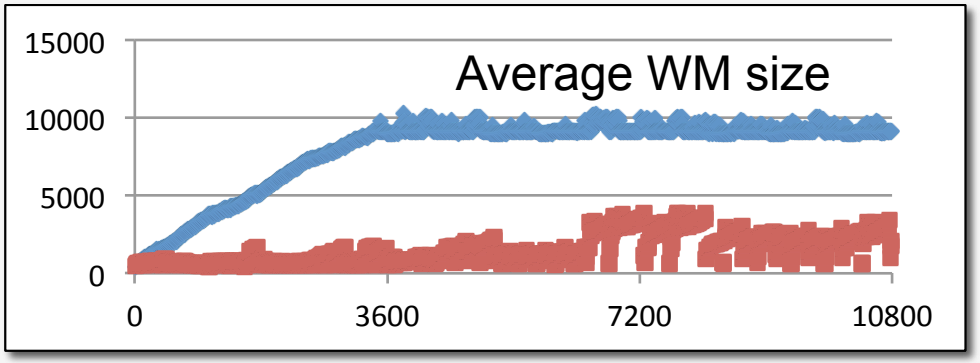
Semantic Memory in Robot Task

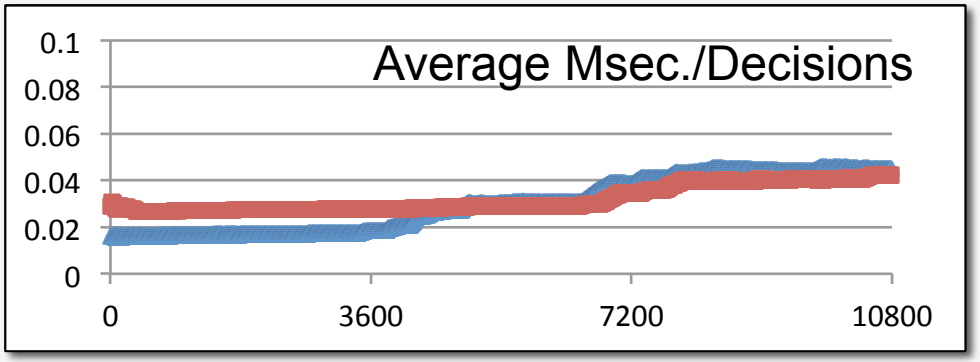
- Stores all map and object data
  - ~7000 elements/run, ~2MBytes
- Retrieves data to WM when necessary
  - ~6000 retrievals
- Removes WM data from distant rooms
  - To minimize working memory and force need for retrieval

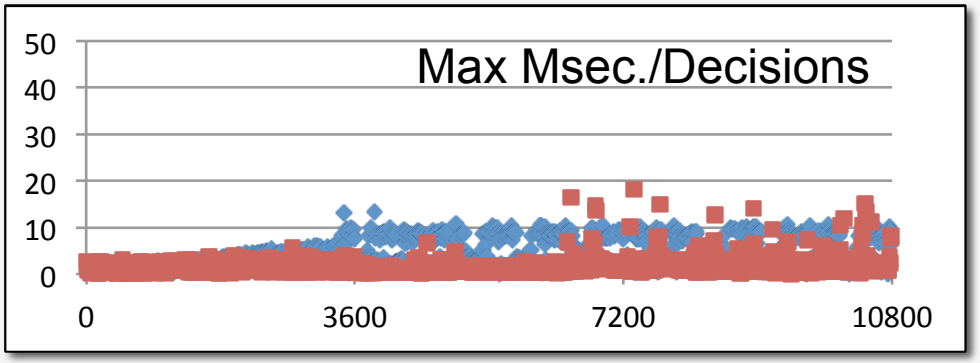
Semantic Memory Results

Map in Working Memory

Map in Semantic Memory
Retrieves from SMEM into WM
as needed







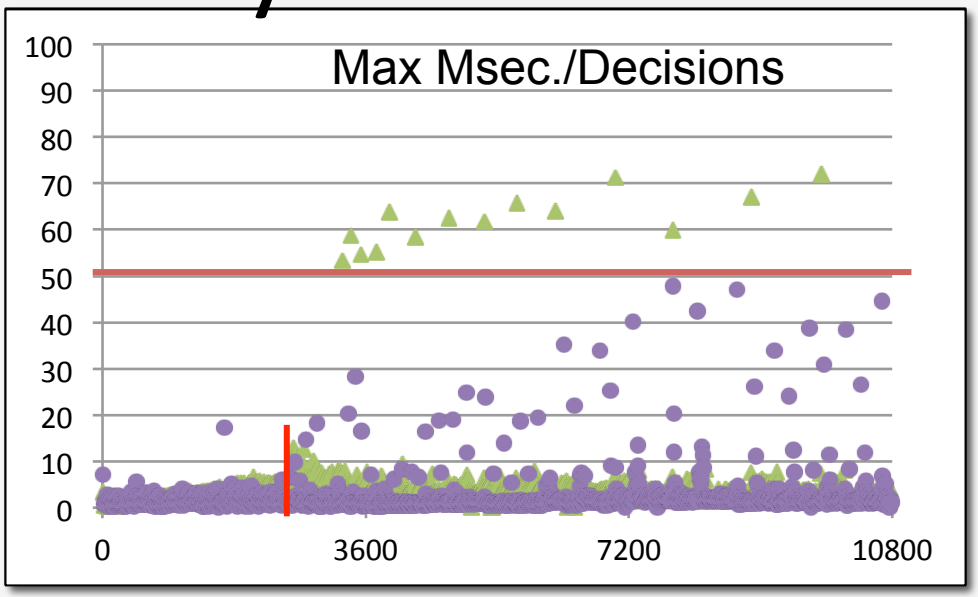
Episodic Memory in Robot Task

- Stores episode when action is taken
  - Episode includes contents of working memory
  - ~4 times/second (42,000 total)
- Remembers blocks that need to be picked up
  - Cue-based retrieval of most recent episode where robot sees block with right features that is not in storage area

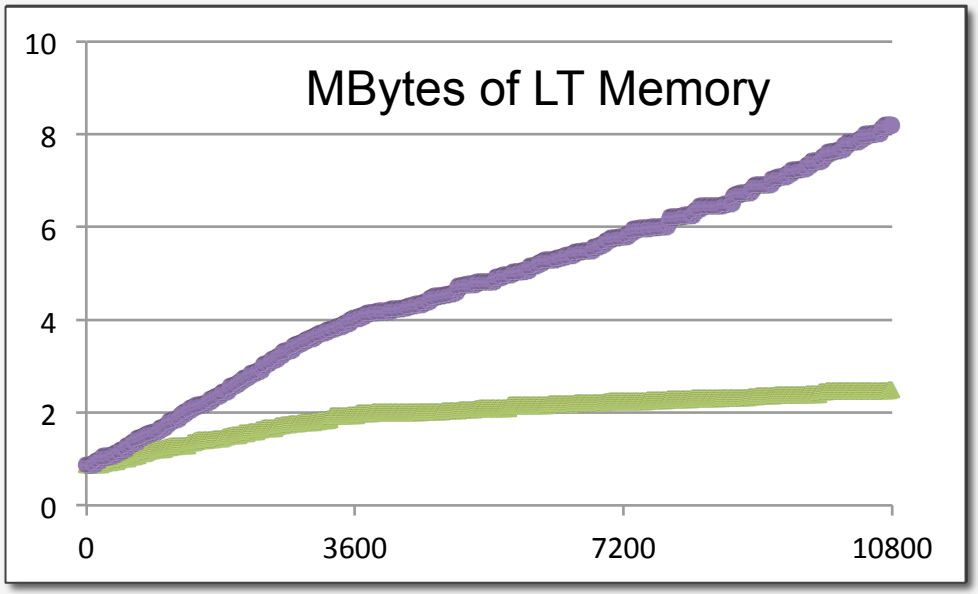
Episodic Memory Results

Episodic Memory with Map in Working Memory

Episodic Memory with Map in Semantic Memory



Episode reconstruction in working memory is a major cost (linear with size of episode).



Nuggets and Coal

- Achieve performance goals for this task
  - 3 hour continually running
  - < 50 max msec./decision
  - 10M memory for SMEM and EPMEM
- Semantic Memory out performs working memory
  - With and without episodic memory
- Scaling to 1 year (X 3,000)?
  - EPMEM + SMEM memory = ~30Gbytes
  - Processing
    - Semantic Memory appears stable, but difficult to extrapolate
    - Episodic Memory appears to grow with at least a log component